METHOD AND SYSTEM FOR EXTRACTING HYDROCARBON FUEL PRODUCTS FROM WASTE MATERIAL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to recyclable materials recovery systems, and more specifically, to a method and system for extracting useable hydrocarbon fuel products from waste material by conversion of fuel pre-products to gas.

2. Background of the Invention

A significant amount of waste material produced by residential and commercial facilities comprises plastics. Unless a recovery and/or recycling system is implemented, these plastics ultimately end up in landfills or are incinerated, producing undesirable gaseous pollutant products and ash. Some plastics may be recycled and used in part to form new plastic products, but it is possible to revert plastics to constituent chemical components or other compounds and re-use these compounds to produce fuel or for other manufacturing purposes.

Other waste materials, such as oilfield sludge (a mixture of tar, sand and dirt), absorbent materials that have been used to

clean up oil spills and byproducts of other manufacturing and refining processes may contain useable hydrocarbon fuel components, also. It would be desirable to be able to process these materials in the same manner as the above-mentioned plastic waste material.

In particular, it is possible to produce a diesel-like fuel from hydrocarbon compounds that may be extracted from plastics and other waste. At high temperatures, the compounds are a gaseous mixture containing various hydrocarbons, aromatics and other gases. The gases may then be further separated and processed by distillation or other refining means to produce various usable fractions. In general, the resulting liquid condensed from the extracted gases cannot be burned in a diesel engine, as the spectrum of hydrocarbons produced from a mixture of plastics, or a solitary plastics contains a high fraction of "hot" components such as octane that will destroy a diesel engine unless the fraction is reduced to tolerable levels via a refining process. In general, all of the product should be useable, as octane can be used to make a gasoline fuel and lighter components may be "cracked" to form propane and synthetic natural gas fuels.

Several existing methods and systems have been proposed to revert plastic materials to gas from which fuel may be produced. In general, these systems fall into two categories: low

temperature vapor extraction methods and high temperature pyrolytic conversion methods. The pyrolytic conversion methods require high energy input and generate gaseous fuel products such as butane and methane which require compression and large volume storage per BTU. The efficiency of conversion is very low, as the long-chain hydrocarbons present in plastics are converted to very short-chain hydrocarbon fuel components, wasting the energy available in the longer chains already present in plastics and other waste material.

Vapor extraction methods in the existing art have a low production throughput and are prone to a build-up of cross-linked polymers that must be removed from the equipment and a build-up of heavy hydrocarbon components that are not effectively removed from the system. They also are susceptible to environmental conditions such as barometric pressure and ambient temperature. These drawbacks have made existing vapor extractio systems not practical for both economic and production volume reasons.

Therefore, it is desirable to provide a method and system for extracting usable hydrocarbon fuel products from waste material in an energy efficient manner having high production throughput.

SUMMARY OF THE INVENTION

The above objective of providing efficient and high-throughput extraction of useable hydrocarbon fuel components from waste material is achieved in a method and system. The method and system introduce waste material to a melting chamber having a substantially constant temperature and a liquid fuel pre-product is generated. The liquid is introduced to a process chamber at a substantially constant higher temperature and a negative relative pressure (vacuum) is applied to cause the liquid to off-gas the useable hydrocarbon fuel components in gaseous form. The liquid is agitated as well as heated to promote off-gassing. The melting chamber and process chamber may be a staged feed system having two different portions and an auger may be used to feed the waste material through the chambers. The remainder of the waste material is ejected at the far end of the process chamber and may be combined with the output of other chambers and re-processed for further extraction of useable fuel components.

The foregoing and other objectives, features, and advantages of the invention will be apparent from the following, more particular, description of the preferred embodiment of the invention, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a simplified pictorial diagram depicting a system in accordance with an embodiment of the present invention.

Figure 2 is a detailed pictorial diagram depicting a system in accordance with an embodiment of the present invention.

Figure 3 is a pictorial diagram depicting details of the processing of plastic material within process chamber **12** of **Figure 2.**

Figure 4A is a pictorial diagram depicting a detailed side view of pressure chamber **19** of **Figure 2.**

Figure 4B is a pictorial diagram depicting a detailed end view of pressure chamber **19** of **Figure 2.**

Figure 5 is a pictorial diagram depicting details of the auger unit **27** of **Figure 2.**

Figure 6 is a pictorial diagram depicting a system in accordance with an alternative embodiment of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring now to the figures and in particular to **Figure 1**, a simplified depiction of a system for extracting hydrocarbon fuel products from waste material in accordance with an embodiment of the present invention is shown. Waste material is introduced to a hopper **1** and is liquified in a liquification chamber **2**. Liqiufication chamber **2** can accept plastic material, which is generally shredded and compressed. The plastic material is melted to form a liquid **3** by heating liqification chamber **2** to a temperature substantially equal to 585 degrees Fahrnheit. The above-stated temperature is chosen as a minimum temperature to reduce a plastic mixture containing typical recyclable plastics to a liquid and a maximum temperature to avoid forming a cross-linked solid. Cross-linked polymers generally have a higher melting point than recyclable plastic waste and will not readily convert to hydrocarbon fuel components via the system once they have been produced by over-temperature. Therefore, the temperature of liquification chamber **2** should be carefully controlled so that no solid plastics remain and so that none of the plastic material becomes cross-linked.

Liquification chamber **2** is included to ensure that solid plastic material is not introduced to further processing, which will be performed at a higher temperature. The higher temperature

processing will form cross-linked chains within any solid plastic material. Processing liquified plastics provides a mechanism for avoiding the overheating of solid plastics and thus the cross-linking of the plastics' hydrocarbon chains. A pump **5** moves the liquified plastics **3** to a process chamber **4**, where the liquified plastics (which contain hydrocarbon fuel pre-products) are further heated to a temperature substantially equal to 850 degrees Fahrenheit and are permitted to off-gas. The above-stated temperature is a maximum temperature chosen to cause the liquified plastic to off-gas rapidly, while avoiding "cracking" of the bydrocarbon fuel products such as decane to shorter-chain hydrocarbon components, as is done in pyrolytic converters. The higher temperature of process chamber **4** is generally above the flash point of the gaseous fuel components that are being extracted, and therefore the system must substantially prevent the introduction of air within process chamber **4** (and possibly liquification chamber **2**). Otherwise the fuel products may combust in the chamber, creating a hazard and wasting the fuel components extracted.

Some off-gassing will also occur in liquification chamber **2** and these gases may be removed by a vent **8A**, but primarily, the gases (which contain hydrocarbon fuel products) will be extracted via a vacuum pump **8**. Vacuum pump **8** is included to remove the gases produced by the off-gassing liquid plastic material **7**.

Without vacuum pump **8**, insufficient gas will exit the system, and the heavier vapor components (such as parrafin) will remain in the system. Additionally, the effects of ambient barometric pressure and temperature on the system are eliminated. A system without negative relative pressure applied to the process chamber will not remove heavier gaseous hydrocarbon fuel components when the outside temperature falls too low. As a result, continued "cracking" of the hyrdocarbon fuel products occurs and under certain ambient conditions, the output will be only lighter components that cannot condense to form a liquid fuel. Additionally, the overall output of a non-vacuum driven system under the above-described conditions will be reduced to a small fraction of the potential system production.

Once the gases are removed, they are introduced to a processing system **9** for condensation of heavier fuel components, further refining of heaviest fuel components and potential extraction and storage of lighter fuel components. But, the lighter fuel components are useful for combustion heating of process chamber **4** and liquification chamber **2** and will generally be used for this purpose.

The present invention may also be adapted (or used in an existing form) for the processing of other material containing usable hydrocarbon fuel pre-products. Drill cuttings or other

waste from oil drilling sites (which is a mixture of sand or dirt and crude oil) may be heated to extract the contained hydrocarbon fuel pre-products and off-gas fuel components. Optionally, liquification chamber may not be required for this type of processing (if the waste material does not contain polymers which will become cross-linked) and systems may be specially adapted in accordance with embodiments of the present invention.

Referring now to **Figure 2**, a plastic reversion system **10**, in accordance with an embodiment of the present invention is shown. A process chamber **12** is formed from a cylindrical pipe with an auger **11** disposed within and passes through within a heating unit **27**. A separate liquification chamber is not implemented within system **10** but is provided by heating a first portion of auger **11** and process chamber **12** (before entering heating unit **27**) to a lower temperature substantially equal to 585 degrees Fahrenheit for the first section of the process chamber **12** via electric heat sheath **28**. Auger **11** is rotated by a drive system **15** at a substantially constant rate. Plastic material chips are introduced to process chamber **12** from a feed hopper **13** and a feed auger **14** may be used to compress the plastic material (and optionally grind the plastic chips from larger portions) for introduction to process chamber **12** under pressure, eliminating introduction of air. Auger **11** drives the plastic material through

process chamber **12** at a substantially constant rate. Both auger **11** and feed auger **14** may be driven by an electric motor and gearbox combination, a hydraulic motor or pneumatic motor depending on requirements of the particular system application. Process chamber **12** is generally a metal pipe, and the diameter of auger **11** and process chamber **12** are determined by throughput requirements. The length of auger **11** and angle of the auger flights are chosen to determine the "dwell time" (the time the plastic material take to travel through process chamber **12**), which is a critical factor in reverting the plastic material to gas.

Process chamber **12** is heated by a heating system comprising a heater **16** for heating air, ducting **17** for delivering the heated air to ports **18** within heating unit **27** that are coupled directly to a pressure chamber **19** that encloses a portion of process chamber **12**. Electic heat sheath **28** may be replaced by a heating system porting air from heater **16** or a second heater, so that the lower liquification temperature may be maintained over the first segment of process chamber **12** that acts as a liquification chamber. Air exits heating unit **27** through ports **20** and is recirculated via a duct **22** and blower **21**, returning to heater **16**. The heating system produces a high pressure air stream around process chamber **12**. The air is heated to raise the temperature of

the portion of auger **11** and process chamber **12** within heating unit **27** to approximately 850 degrees fahrenheit.

The plastic material undergoes phase changes as it is driven around the heated auger **11**, and near the end of auger **11** exit pipes **23** are connected to remove the gaseous mixture produced within process chamber **12** and at the end of auger opposite feed hopper **13**. The gas mixture removed at exit pipe **23** is a mixture of many different compounds and gaseous elements and may be condensed, refined or otherwise processed to yield useful products. In general, a very clean-burning fuel product may be refined from the gaseous mixture. Yield output is approximately one gallon of distillate from eight to nine pounds of plastic material. Waste material **25** from the process, called "char" or ash is dropped from a lower exit pipe **24** to a char pit **26** for disposal.

A vacuum system **29** applies a negative relative pressure to process chamber **12**, assisted by an "air dam" that is created by compressed plastic material at a point along auger **11** before the plastic material has reached a completely liquid state. Vaccuum system **29** generates a suction that draws against the air dam, generating a negative relative pressure throughout process chamber **12**, which aids in the conversion of the plastic material

from liquid to gas and increases the yield of the system to a practical production level.

Referring now to **Figure 3**, the processing of plastic material within the system of **Figure 2** is depicted with reference to a detailed representation of process chamber **12**. Feed auger **14** compresses plastic chips from feed hopper **14** and introduces them to auger **11** within process chamber **12**. The rotation of auger **11** moves the plastic material, which is still in solid form, and heat is transferred from heat sheath **28** to auger **11** and process chamber **12** to melt the plastic material.

At the end of length **L1**, the plastic material has become liquified and pools on the bottom of process chamber. It is within length **L1** that the approximate location of air dam lies (prior to complete liquification), and a negative relative pressure will be exerted on the plastic material ahead of this location. In length **L2**, the plastic material becomes completely liquified and within length **L3**, the material is converted to gaseous form with some solid waste product remaining (char). At the end of process chamber **12**, the char are ejected for disposal or further processing. The gases are removed for processing by vents located within length **L3** and coupled to a vacuum system.

While the above description and illustrations depict a process having generally defined phase boundaries and temperatures and the description suggests uniform composition, in practice, the plastic material introduced to feed hopper **13** may comprise many different plastic materials, and the mixture may vary substantially over time. Therefore, different temperatures may be used and the material within process chamber **12** may transition to liquid form at varying locations. But, it has been found that for a well-mixed feed stock, the behavior of the plastic material is very homogeneous, approximating the behavior of an average material.

Critical to the operation of the system is that the rate of feed and temperature within process chamber **12** be carefully controlled. If the temperature of liquification portion of process chamber **12** is too low, or the rate of feed is too high the plastics will not be completely melted before reaching length **L3** and the solid polymer materials will cross-link, forming a very tough product that will not gassify, and may not move through the process chamber at all, jamming system **10**, or producing excessive waste at the char output. If the temperature of the liquification portion of process chamber is too high, the material will cross-link rather than melt.

If the temperature of process chamber **12** within heating unit **27** is too low, or the rate of feed too high, little or no off-gassing will occur, producing excessive waste at the char output and a low yield at the gas output. The plastics reverted by system **10** generally begin to off-gas at a temperature higher than 400 degrees fahrenheit, so the operating temperature of heating unit **27** (850°F) ensures that the process temperature will be high enough to revert the plastics, but low enough to avoid cracking of the gases that have been extracted. In general, the rate of feed and temperature may be selected based on the materials being processed, average characteristics and other criteria to maximize throughput, conversion efficiency or both.

Referring now to **Figures 4A** and **4B**, details of pressure chamber section **19A** within pressure chamber **19** of **Figure 1** are depicted. **Figure 3A** is a side view of a pressure chamber section **19A** (there are three such sections making up pressure chamber **19** of **Figure 1**). Pressure chamber section **19A** comprises an inner pipe **41** and an outer pipe **40**. The cylindrical wall of inner pipe **41** is perforated (to avoid the formation of "hot spots") and is connected to outer pipe **40** by a plurality of pipes that protrude through to the outer wall of outer pipe **40**, supporting inner pipe **41** along with process chamber **12** (**Figure 1**). A port **18A** is directed at pressure chamber **19** to supply heated air around

pressure chamber **19** to heat process chamber **12. Figure 4B** depicts a side view of pressure chamber **19,** showing the orientation of pipes **42** and port **18A,** as well as the location of perforations **43.**

Referring now to **Figure 5,** details of heating systems within the system of **Figure 2** are shown. Heat sheath **28** is an electric heater coupled to a power system **52,** but may be replaced with a air circulated gas system as used in heating unit **27.**

Heating unit **27** contains ports **18A** and **18B** that supply heated air to chambers **50,** heating pressure chamber sections **19A** and thus process chamber **12.** Ports **20** return air to the heating system forming a closed loop through chambers **50.** Port **18A** differs from the other two ports **18B** in that the outlet location is disposed slightly further along process chamber **12,** providing more heat toward the end of length **L1** of **Figure 3.**

Referring now to **Figure 6** a system in accordance with an alternative embodiment of the invention is shown. In the alternative embodiment depicted, six process chambers **61A** are placed in parallel and all pass through a common heating unit **62,** providing more efficient use of the heating system. The char outputs of process chambers **61A** are combined in a piping manifold **64** and are introduced to a secondary process chamber **61B,** that

extracts any remaining gaseous fuel products. The char output of process chamber **61B** is then removed for discard or use. While the illustration shows a flattened parallel construction, in practice, the system may be formed with process chambers **61A** arranged so that their cross sections form a ring, or they may be closely packed to improve coupling to heater **62** and reduce the exterior size of heater **62**.

While the invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form, and details may be made therein without departing from the spirit and scope of the invention.